UNIVERSITI PUTRA MALAYSIA

DEVELOPING HIGHLY DIMENSIONALLY STABLE MULTI-LAYERED ORIENTED STRAND BOARD FROM ACACIA MANGIUM WILLD. IMPREGNATED WITH LOW MOLECULAR WEIGHT PHENOLIC RESIN

ONG LAY LEE

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By

ONG LAY LEE

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirement for the Degree of Master of Science

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DEDICATION

… In loving memory of my Grandfather
Ong Soon Seng (1912 – 1991)

Always in my thought.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

DEVELOPING HIGHLY DIMENSIONALLY STABLE MULTI-LAYERED ORIENTED STRAND BOARD FROM *ACACIA MANGIUM* WILLD. IMPREGNATED WITH LOW MOLECULAR WEIGHT PHENOLIC RESIN

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Chairman: Paridah Md. Tahir, Ph.D.

Faculty: Forestry

This study was carried out to investigate the effectiveness of pre-treatment of wood strands with low molecular weight phenol formaldehyde (LPF) resin to improve the dimensional stability of oriented strand board (OSB). The origin and extent of thickness swelling (TS) in OSB made from *A. mangium* Willd. were also investigated. Three- and five-layered OSBs were fabricated with 5% resin solid based on oven dry weight of wood strands (w/w) of phenol formaldehyde (PF) resin as a binder.

The origin of TS was determined by using coating method where the edges and surfaces of the panel were coated with oil-based pigmented paint. To assess the degree of TS, the OSB specimens were sliced/sectioned into four layers through the thickness direction of the panel and were subjected to 24 hours of cold water soaking. The results showed that the water uptake by the panel occurred mainly through the four edges. The board surfaces absorbed 20% more water than those in the core. The distribution of TS and water absorption (WA) for the sectioned layers were found to resemble that of the

vertical density profile of the OSB panel. The surface layers of the panel had relatively higher density, thus contribute significant influence over the TS of the board. The Pearson ratio showed a very high correlation between the board density and TS (R^2 = 0.87 and 0.96 for three- and five-layered OSB, respectively). The untreated five-layered OSB (control) was found to be more stable than that of three-layered due to the presence of higher resin content in the surfaces (fine particles).

Since more than 30% of the control specimens registered TS exceeded 12%, an attempt was made to enhance the dimensional stability of the OSB. The wood strands were impregnated with an LPF resin prior to spraying with a conventional PF resin (5% w/w). It was found that the mechanical properties and dimensional stability of the panels were significantly affected by both the amount of LPF resin incorporated, i.e. 2%, 5% and 7% (w/w), and board structure (three- and five-layered). All the panels treated with LPF resin produced significantly higher modulus of rupture (MOR) than the control panel; the three-layered OSB apparently had a higher MOR than did five-layered OSB. After a hot and cold water treatment, both three- and five-layered panels impregnated with 7% LPF retained 67% and 58% of their MOR respectively. The internal bond (IB) strength increased with an increasing level of LPF; where OSB treated with 7% LPF showed twice the value of the control. Boards impregnated with LPF showed a dramatic decrease (27%) in TS, in particular the three-layered boards, even at a low LPF loading of 2%. High dimensional stability at 61% of anti-swelling efficiency (ASE) was attained by three-layered boards treated with 7% LPF. Increasing the amount of LPF resulted in significant reduction in the TS and the parallel and perpendicular linear expansion ($LE_{//}$

and $LE_{\perp}$ respectively) when the specimens were exposed to 80% relative humidity (RH). The $LE_{\perp}$ was found to be higher than $LE_{//}$ irrespective of LPF level.

Even though the LPF treatment had successfully reduced the TS of the OSB, the IB obtained was not favourable due to insufficient curing of the resin. To confirm this, the effect of press times (7.5, 10.5 and 11.5 minutes) on the IB strength of the five-layered OSB was examined. The study shows that the IB of the OSB was significantly improved by applying longer press time. Pressing the boards for 11.5 minutes doubled the IB strength to 0.4 MPa. Even though the MOR was not significantly affected by the extended press time, the stiffness (modulus of elasticity, MOE) was markedly improved. The use of longer press time apparently resulted in better retention of both the MOR and MOE (after 2-hour boiling). The dimensional stability properties i.e. TS, WA and LE of the phenolic-pretreated OSB were also enhanced when longer press time was used.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Master Sains

PEMBUATAN PAPAN TATAL BERORIENTASI PELBAGAI LAPIS YANG BERKESTABILAN DIMENSI TINGGI DARI *ACACIA MANGIUM* WILLD. DENGAN PENYERAPAN PEREKAT FENOL FORMALDEHID YANG BERJISIM MOLIKUL RENDAH

Oleh

ONG LAY LEE

Ogos 2002

Pengerusi: Paridah Md. Tahir, Ph.D.

Fakulti: Perhutanan

Pengajian ini adalah untuk menyelidik keberkesanan pra-rawatan fenol formaldehid yang berjisim molikul rendah (LPF) keatas tatal kayu demi peningkatan kestabilan dimensi panel tersebut. Punca pengembangan ketebalan (TS) papan tatal berorientasi (OSB) yang diperbuat daripada *A. mangium* Willd. juga diselidiki. Papan tatal berorientasi tiga- dan lima-lapis dilekat dengan menggunakan 5% pepejal perekat berdasarkan berat kering ketuhar tatal kayu (w/w) fenol formaldehid (PF) yang digunakan sebagai perekat.

Punca TS diperolehi dengan menggunakan kaedah penyalutan dimana tepi dan permukaan panel disalut dengan cat minyak. Untuk mengetahui tahap TS, spesimen OSB dipotong kepada empat lapis dari arah ketebalan dan direndam dalam air sejuk selama 24 jam. Keputusan menunjukkan keupayaan papan untuk menyerap air (WA) didapati lebih tinggi melalui tepinya. Permukaan papan didapati menyerap 20% lebih air berbanding

dengan lapisan tengah. Corak TS dan WA bagi setiap potongan lapis tersebut didapati selari dengan perubahan corak kepadatan secara menegak pada OSB. Lapisan permukaan papan mempunyai kepadatan yang lebih tinggi, maka mempengaruhi TS papan secara ketara. Nisbah 'Pearson' menunjukkan kewujudan perhubungan rapat di antara kepadatan papan dan TS (R^2 = 0.87 dan 0.96 untuk OSB tiga- dan lima lapis masing -masing). OSB lima-lapis tanpa rawatan (kawalan) didapati lebih stabil daropada tiga-lapis disebabkan kandungan perekat yang lebih tinggi pada permukaannya (serpihan halus).

Memandangkan terdapat lebih dari 30% daripada spesimen kawalan merakamkan TS melebihi 12%, usaha telah dilakukan untuk meningkatkan sifat kekuatan dimensi OSB. LPF telah diserapkan ke dalam tatal kayu sebelum disemburkan dengan perekat PF konvensional (5% w/w). Adalah didapati bahawa sifat kekuatan mekanikal dan kestabilan dimensi bagi panel yang telah dirawat amat dipengaruhi oleh jumlah perekat yang diserapkan, iaitu 2%, 5% dan 7% (w/w), dan struktur papan (tiga- dan lima-lapis). Semua panel yang dirawat dengan perekat LPF mencapai modulus kehancuran (MOR) yang lebih tinggi berbanding dengan tatal kawalan secara ketara. Panel tiga-lapis mempunyai MOR yang lebih tinggi daripada panel lima-lapis. Selepas rawatan air panas and sejuk, kedua-dua panel tiga- dan lima-lapis yang dirawat dengan 7% LPF masing-masing dapat mengekalkan 67% and 58% daripada kekuatan asal mereka. Kekuatan lekatan dalaman (IB) meningkat dengan peningkatan kadar LPF dimana papan dirawat dengan 7% LPF menunjukkan peningkatan kekuatan tersebut secara berganda. Panel yang dirawat dengan LPF juga mempamerkan pengurangan TS (27%) secara mendadak, terutamanya panel tiga-lapis walaupun pada rawatan LPF yang rendah (2%). Kestabilan dimensi yang tinggi pada 61% keupayaan menentang pengembangan (ASE) telah dicapai oleh panel tiga-lapis yang dirawat dengan 7% LPF. Meninggikan amaun LPF telah menurunkan TS, pengembangan linear selari dan melintang ($LE_{//}$ and $LE_{\perp}$ masing-masing) secara ketara apabila didedahkan kepada 80% kelembapan bandingan (RH). $LE_{\perp}$ adalah lebih tinggi daripada $LE_{//}$ pada semua level LPF.

Walaupun rawatan LPF telah berjaya mengurangkan TS pada OSB, IB yang diperolehi adalah tidak baik disebabkan perekat tidak matang dengan secukupnya. Untuk memastikan kenyataan ini adalah benar, kesan masa penekanan (7.5, 10.5 dan 11.5 minit) keatas kekuatan IB turut dikaji untuk OSB lima-lapis. Keputusan menunjukkan IB pada OSB telah dimajukan secara ketara dengan menggenakan masa penekanan yang lebih panjang. Kekuatan IB telah dipertingkatkan sehingga hampir dua kali ganda untuk masa penekanan 11.5 minit kepada 0.4 MPa. Walaupun MOR tidak dipengaruhi oleh masa penekanan, modulus kekenyalan (MOE) telah dimajukan secara ketara. Penggunaan masa penekanan yang lebih panjang telah menyumbangkan kepada pengekalan kekuatan asal OSB (MOR dan MOE) yang lebih tinggi setelah direndam dalam air mendidih selama dua jam. Kestabilan dimensi iaitu, TS, WA dan LE pada OSB yang menjalani pra-rawatan fenolik juga dipertingkatkan dengan menggunakan masa penekanan yang lebih panjang.

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I certify that an Examination Committee met on 29th August 2002 to conduct the final examination of Ong Lay Lee on her Master of Science thesis entitled "Developing Highly Dimensionally Stable Multi-Layered Oriented Strand Board from *Acacia mangium* willd. Impregnated with Low Molecular Weight Phenolic Resin" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (High Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

JALALUDDIN HARUN, Ph.D.
Faculty of Forestry/Institute of Advanced Technology
Universiti Putra Malaysia
(Chairman)

PARIDAH MD. TAHIR, Ph.D.
Faculty of Forestry
Universiti Putra Malaysia
(Member)

WONG EE DING, Ph.D.
Faculty of Forestry
Universiti Putra Malaysia
(Member)

RAHIM HJ. SUDIN, Ph.D.
Wood Composite Unit
Forest Research Institute Malaysia
(Member)

AINI IDERIS, Ph.D.
Professor/Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 23 OCT 2002

This thesis submitted to the Senate of Universiti Putra Malaysia has been accepted as fulfillment of the requirements for the degree of Master of Science. The members of the Supervisory Committee are as follows:

PARIDAH MD. TAHIR, Ph.D.
Faculty of Forestry
Universiti Putra Malaysia
(Chairman)

WONG EE DING, Ph.D.
Faculty of Forestry
Universiti Putra Malaysia
(Member)

RAHIM HJ. SUDIN, Ph.D.
Wood Composite Unit
Forest Research Institute Malaysia
(Member)

AINI IDERIS, Ph.D.
Professor/Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

ONG LAY LEE

Date: 23 – 10 – 2002

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LIST OF ABBREVIATIONS

ANOVA	Analysis of variance
IB	Internal bonding
IPL	Incorporated phenol formaldehyde level
JIS	Japanese Industrial Standard
LE	Linear expansion
$LE_{//}$	Linear expansion in parallel direction to strand alignment
$LE_{\perp}$	Linear expansion in perpendicular direction to strand alignment
LPF	Low molecular weight phenol formaldehyde
MC	Moisture content
MOR	Modulus of rupture
MOE	Modulus of elasticity
Mw	Molecular weight
OSB	Oriented strand board
PF	Phenol formaldehyde
PT	Press time
RH	Relative humidity
SEM	Scanning electron microscopy
TS	Thickness swelling
VDD	Vertical density distribution
WA	Water absorption

CHAPTER 1

INTRODUCTION

Oriented Strand Board (OSB) is no longer a stranger to the world wood based panel market. It is one of the most significant developments in panel technology in this century. Producing OSB with greater bending strength in one-panel direction (usually the length direction) results in a product much like traditional plywood. Such panels are used almost entirely in structural applications in the same way as plywood. The OSB segment of the wood based composite industry has become an important part of the structural panel business in recent years. Its growth has been the greatest in the United States (U.S.) and Canada. OSB continues to gain wider acceptance in both the United States and Japanese housing markets and is seen as the most potential investment in the Southeast Asia region. The growth in OSB capacity is leading the response to the timber crisis and will help to defend wood products from competitive non-wood products for years to come. Improvements in OSB properties could make it more competitive for structural uses.

Wood, like all other plant materials, is laid down from aqueous solution. The cellulose, hemicellulose, and lignin polymers formed are no longer soluble in water, but water still dissolves in them to form solid solutions on the polar hydroxyl groups. Water is held within the cell wall structure by hydrogen bonding (Stamm 1964; Skaar 1972). Wood composite panel products are known to be hygrothermal-viscoelastic materials. Therefore, moisture, temperature, load and time factors should be considered collectively and dependently when assessing the serviceability or durability of these products upon exposure to changing environment. Furthermore, the load-carrying capacity of wood-composite panels will be changed substantially when they are subjected to changing relative humidity.

All wood products are hygroscopic, and shrink and swell when subjected to environmental conditions that cause desorption and absorption of water. Wood is dimensionally stable when the moisture content is above the saturation point and changes dimension as moisture is gained or lost below that point. Considerable concern is being expressed by the panel industry over excessive thickness swelling, particularly in OSB since it is usually used in building construction. The magnitude of the dimensional change of OSB is much greater in the thickness direction than would be expected from the normal shrinking and swelling of solid wood. The additional thickness swelling that occurs when OSBs are exposed to moisture – greater than that normally expected for wood material – is due to the release of residual compressive stresses imparted to the board during the pressing of the mat in the hot press. It is known that compressive failure of at least a portion of the wood particles is required to produce particleboard. The moisture content reduction while the mat is restrained in the hot press reduces the plasticity of the wood and results in a "set" of these compressive stresses. At some future date when the moisture content increases, the additional moisture will plasticize the wood and permit these stresses to be relieved, allowing expansion in the thickness direction (so-called springback). Subsequent redrying will result in thickness shrinkage equal only to the shrinkage of the particles; none of the compressive stress released will be recovered